Final Report to Virginia Coastal Zone Management Program

INSTAR Stream Assessment Program
FY04 Task 84

Submitted by:

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INteractive ***S***tream ***A***ssessment ***R***esource ***(INSTAR)***

Background

A key role of Virginia's natural resources agencies is the identification, restoration, and protection of streams, rivers, and riparian corridors that contribute important ecosystem services or represent significant ecological resources. Challenges associated with these important efforts include: 1) development and application of objective, quantitative, and diagnostic stream assessment protocols and 2) defining a set of measurable and appropriate stream conditions, based on empirical data, as goals for restoration and protection efforts. Both of these challenges are dependent on an understanding of, and comparison to, relevant reference conditions that describe accurately and quantitatively the ecological potential of streams and rivers within a specific region. In Virginia, the lack of relatively undisturbed streams to serve as reference systems is especially problematic in the Coastal Zone, Piedmont, northern Virginia, and the Shenandoah Valley, and compromises stream assessment and protection activities for these regions.

Recent studies in Virginia and elsewhere also suggest that results from standard stream assessment protocols (e.g. Rapid Bioassessment Protocols *versus* Indices of Biotic Integrity *versus* geomorphologic stream classification) often present conflicting views of stream health or status, even when the data on which assessments are based are temporally and spatially synoptic. The lack of agreement among standard stream assessment methods is problematic and may limit the appropriate application of these widely-used protocols, even where valid, regional reference conditions are available. Furthermore, current approaches to stream assessment may not support useful comparisons of conditions across broad spatial (i.e., geographic) scales or among major watersheds.

A New Approach to Stream Assessment

In response to the problems outlined above, Virginia Commonwealth University, the Virginia Department of Conservation and Recreation, and the Coastal Management Program of DEQ initiated a multi-phase project in 2003 to develop an integrative, objective, and statistically valid stream health assessment application (Figure 1). The project uses high quality archival data, combined with extensive, new data collected by the VCU stream assessment team, to develop a broad suite of georeferenced databases of aquatic resources, including fish and macroinvertebrate communities, instream and riparian habitat, and geomorphological data. These databases are the foundation for the ***IN***teractive ***ST***ream ***A***ssessment ***R***esource (***INSTAR***) application: an online, interactive mapping and database application designed to quantitatively assess stream conditions based on comparisons among a suite of integrative, multimetric indices and 'virtual' reference stream models.

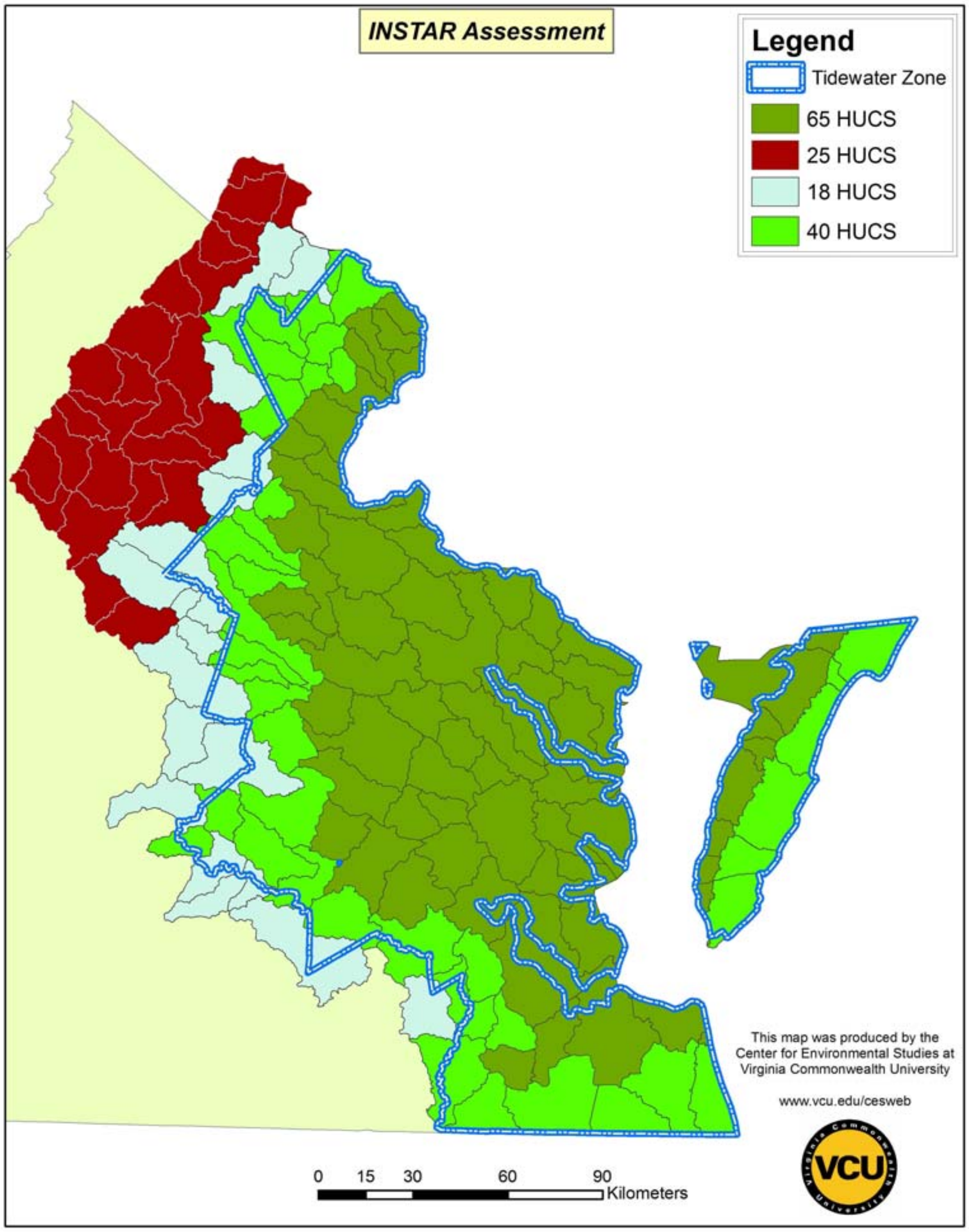


Figure 1. Distribution of Atlantic Slope hydrologic units (HUCs) in Virginia. Previous INSTAR efforts (through DCR grants) focused on the 65 HUCs that comprise the core of the coastal zone (dark green). The current grant (FY04 Task 84) expanded sampling for the INSTAR database to include an additional 47 HUCs that are fully, or largely, encompassed by the Tidewater jurisdictional boundary (light green and selected light blue). At least 40 of the HUCs (light green) were sampled at a high resolution to support reach-level assessment being conducted for the 65 HUCs (dark green) under FY04 Task 93.04.

INSTAR, and the extensive aquatic resource database on which it runs, were developed to support a variety of stream assessment, management and planning activities aimed at restoring and protecting water quality and aquatic living resources throughout the Commonwealth. The project is currently focused on developing an aquatic resources (blue infrastructure) database and stream health assessment protocols for Virginia's portion of the Chesapeake Bay watershed. In addition, regional reference stream models (i.e., *virtual* streams) for both non-tidal and small to medium-sized tidal tributaries will be developed as criteria for prioritization of candidate streams and watersheds for protection and restoration, objective and quantitative performance measures, and as a decision support tool for environmental planning and implementation. The *INSTAR* program (http://instar.vcu.edu) and related applications developed by VCU leverage cutting-edge, information technologies (e.g. MS SQL, ArcIMS, ArcGIS Server) and an expanding database of high-quality, geospatial information to conduct both statewide (hydrologic unit scale) and site/reach specific assessments of stream and river health throughout the Commonwealth. Currently, *INSTAR* has compiled information on approximately 1,600 Virginia streams and *INSTAR* databases comprise over 175,000 records, including a substantial amount of new data for the Coastal Zone.

Methods

Sample Site Selection:

Selection of study sites in the Virginia Coastal Zone was based on a stratified (by stream order), probabilistic design to be representative of stream conditions within the watershed. The number of sites sampled is based on the results of a statistical power analysis, the amount of available resources, and the quantity and quality of archival data for the basin. ArcGIS software is used to generate points (study site locations) in 14 digit watersheds, using a probabilistic site selection program. Points represent the center points of (minimum) 150-meter study reaches.

Fish Collection Methods:

Within each geo-referenced reach (150-200 m), fishes are sampled quantitatively using electrofishing equipment (backpacks, tote barge units, boats (Smith-Root)) and standard methods. Sampling proceeds in an upstream direction capturing all fish possible from all habitats. Backpack and tote barge sampling is performed throughout the entire reach in a single pass. Boat electrofishing may include additional sampling effort depending on stream width and habitat variability. Electrofishing effort (seconds) is then recorded and the fish are identified to species, enumerated and examined for anomalies prior to being released unharmed to the sampling reach. A small voucher collection of all species collected is maintained at the Virginia Commonwealth University Fish Museum.

Macroinvertebrate Collection Methods:

Macroinvertebrates were collected using modified EPA Rapid Bioassessment Protocols (RBP III) for single habitat collections (Barbour et al. 1997). D-frame dip nets were used to sample macroinvertebrates from major habitat types found within each 150-meter study site. Examples of habitat types include undercut banks, hard substrate (gravel, etc.) riffles, leaf litter, and woody debris. Each habitat type was sampled separately. Dip nets were swept, jabbed, and/or kicked in and through habitats in order to secure a representative sample of the macroinvertebrate assemblage. Samples were processed in the laboratory where the first 200 organisms encountered were identified to the lowest possible taxon (generally at the genus level) and enumerated.

EPA Rapid Habitat Assessment

An evaluation of habitat quality is critical to any assessment of ecological integrity and should be performed at each site at the time of the biological sampling. In general, habitat and biological diversity in streams and rivers are closely linked. In the EPA protocols, the definition of "habitat" is narrowed to the quality of the instream and riparian habitat that influences the structure and function of the aquatic community in a stream. Altered habitat structure is considered one of the major stressors of aquatic systems and may obscure the effects of other environmental stressors. The assessments performed by many water resource agencies include a general description of the site, a physical characterization and water quality assessment, and a visual assessment of instream and riparian habitat quality. Some states (e.g., Idaho DEQ and Illinois EPA) include quantitative measurements of physical parameters in their habitat assessment. Together these data provide an integrated picture of several of the factors influencing the biological condition of a stream system. These assessments are not as comprehensive as needed to adequately identify all causes of impact. However, additional investigation into hydrological modification and drainage patterns can be conducted, once impairment is noted. The habitat quality evaluation can be accomplished by characterizing selected physicochemical parameters in conjunction with a systematic assessment of physical structure. Through this approach, key features can be rated or scored to provide a useful assessment of habitat quality.

Geomorphology Assessment:

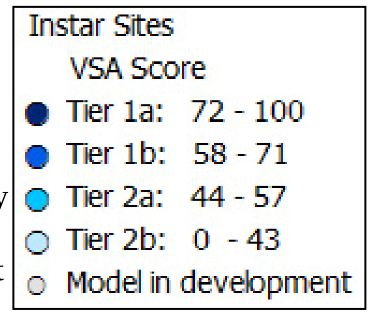
At selected stream locations, a limited evaluation of geomorphology was conducted, including the following measurements using standard protocols:

- Maximum depth: Thalweg elevation - bankfull elevation
- Flood-prone width: Measured at the elevation of twice the Max Depth of the channel at bankfull
- Entrenchment: Flood Prone Width / Bankfull Width
- Width to depth ratio: Bankfull Width / Mean Bankfull Depth
- Incisement: Top of Bank / Bankfull Elevation

The INSTAR interface displays a stream profile for sites with geomorphologic data.

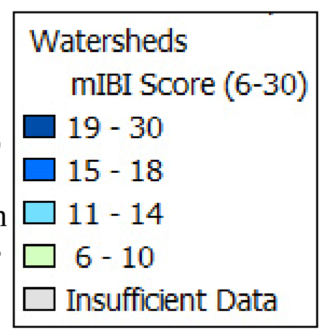
Stream and Watershed Integrity Assessment:

Data are compiled in Access® databases and application macros within INSTAR calculate over 50 separate metrics and ecological variables, including those typically generated for the Index of Biotic Integrity (IBI), Rapid Bioassessment Protocol (RBP), Rapid Habitat Assessment (RHA), and Rosgen-type stream morphology classification. Variables and metrics are then subjected to ordination and cluster analysis using unimodal models (e.g. correspondence analysis (CA), detrended correspondence analysis (DCA), and canonical correspondence analysis (CCA)) and linear response models (e.g. principal components analysis (PCA), multiple regression techniques). The site scores (i.e., coefficients from the final response model) are entered as the response variable and significant ($P<0.05$) biotic and abiotic variables and metrics are entered as explanatory variables, and used to develop a series of reference stream models (i.e., *virtual* streams). We used Gower's similarity index to compare empirical scores obtained from sampled stream reaches to the appropriate virtual reference stream, generating an index of stream health (i.e ***Virtual Stream Assessment, VSA score)*** as a measure of percent comparability to the appropriate (*virtual*) reference condition model. High percent comparability scores (> 75%) are assumed to represent streams with high ecological integrity.



Current reference stream models for upper and lower Coastal Plain streams include variables representing fish and macroinvertebrate assemblage structure, instream habitat, and geomorphology, and have substantial explanatory power (R^2 up to 0.74). This integrative approach eliminates many of the limitations typically associated with traditional bioassessment methods (e.g. RBP, IBI), including lack of appropriate reference sites and stream classifications that are based on a single ecological component (e.g. biotic *versus* abiotic, fishes *versus* macroinvertebrates) that may not be diagnostic under many conditions.

For watersheds and river basins, selected 'universal' metrics (e.g. combined native species richness, percent of pollution-tolerant species, combined non-indigenous species richness) are also used by *INSTAR* to generate a modified Index of Biotic Integrity (mIBI) that classifies each of Virginia's 494, 14-digit watersheds (hydrologic units, HUCs) as a function of stream health, using both quantitative and qualitative (species occurrences) records available for the watershed. Using these two novel approaches, INSTAR is able to support integrated stream health and watershed condition assessments at *broad* (statewide mIBI classification of HUCs) and *fine* (percent comparability to virtual reference stream models) geospatial scales. Appropriate quality assurance and control (QC/QA) procedures are followed for all *INSTAR* field and laboratory protocols.



Categories and breakpoints for both **VSA** and **mIBI** scores are generated dynamically based on statistical distribution criteria (e.g. means and standard errors) for pooled scores. Tier IA streams and watersheds represent the highest ecological integrity for blue infrastructure of the region. In contrast, Tier IIB scores represent substantially degraded aquatic systems, compared to other sites in the region. Maps and additional mIBI results are found in the FY04 Task 93.04 final technical report.

Utility of INSTAR

The *INSTAR* application (http://instar.vcu.edu) is an interactive, internet-based (ArcIMS) program that supports user-driven database queries, mapping functions, and quantitative biological and habitat assessments of stream reaches and watersheds, using algorithms and ecological models that compare selected sites to appropriate regional reference conditions. *INSTAR* is accessible from most computers via the internet and allows both technical and non-technical users to conduct sophisticated GIS and database tasks using an extensive stream database and multiple geospatial data layers. *INSTAR* is currently being used by a wide range of local, state, and federal agencies, academic researchers, and citizen-scientists. Funding for INSTAR has been provided by the Virginia Department of Conservation and Recreation, Virginia Coastal Zone Management Program (DEQ), EPA, and NOAA. For more information, visit http://instar.vcu.edu or contact Dr. Greg Garman, VCU Center for Environmental Studies at ggarman@mail2.vcu.edu or Dr. Len Smock, VCU Department of Biology, lsmock@mail1.vcu.edu.

Specific Accomplishments under the Current Grant
(FY04 Task 84 – Oct. 1, 2004 to June 30, 2006)

1.) Field Sampling in 47 Additional Hydrologic Units

During the project period, extensive field sampling was conducted by VCU personnel in several new locations, including the Atlantic slope of the Eastern Shore and areas that comprise the Tidewater jurisdictional area of Virginia (Figure 1). At total of 47 additional hydrologic units (HUCs) were incorporated into the INSTAR database. Specifically, sampling as outlined above was conducted using standard field protocols at n=206 probabilistic sites. Samples were processing in the field or were returned to VCU for further processing and analysis. In addition, archival data sources (e.g. VDGIF, EPA, DEQ, VDNH databases) were 'mined' for records that satisfied strict criteria for INSTAR data development. New and archival data generated represented fish and macroinvertebrate assemblages and instream habitat and were subjected to approved QA/QC procedures prior to posting on the INSTAR website. Approximately 17,000 new and quantitative records were produced by this extensive sampling and data mining effort, which effectively incorporated—for the first time—each of the sub-basins listed above for INSTAR-based assessment. This objective was fully accomplished under the current grant.

2.) Develop New Stream Models

Using the additional data, new ‘virtual’ stream models were developed, based on the multivariate, statistical methods described above for upper Coastal Plain and lower Piedmont physiographic provinces and separately for first, second, and third order stream types. These models complement existing models for the lower Coastal Plain in Virginia and expand significantly the geographic scope of INSTAR-based stream health assessments. Models are used to classify specific stream reaches or HUCs based on percent comparability to appropriate, regional reference stream models (i.e., *virtual* streams) described in the above text. Stream reaches with strong (>75%) reference comparability scores are characterized by high ecological integrity and exceptional physicochemical conditions. In contrast, stream reaches with poor (<25%) reference comparability scores exhibit degraded ecological integrity and compromised physicochemical conditions. Specific model parameters are described at www.instar.vcu. This objective was fully accomplished under the current grant.

3.) Data Mining and New Data Layers

A substantial effort was devoted by VCU to successfully incorporate high-quality, quantitative, archival data from multiple sources into the expanding INSTAR Virginia stream database. Sources and potential sources of relevant stream data included: Virginia Department of Environmental Quality, Virginia Department of Game and Inland Fisheries, Virginia Natural Heritage Program, EPA’s EMAP program, Potomac River Basin Commission, and USGS. After resolving data compatibility issues and applying specific metadata criteria (e.g. geospatial resolution), useful data were subjected to additional QA procedures and then incorporated on VCU’s server. In two cases (DEQ ProbMon and Natural Heritage VCLNA), data are displayed by the INSTAR map interface as separate datalayers. Other data were simply incorporated into the INSTAR database. As a result of this extensive data mining effort, approximately 30,000 additional records, representing approximately 500 stream locations throughout Virginia, were added to the INSTAR database and will be, or are now, accessible through the application. Currently, over 1,300 stream locations are represented within INSTAR (Figure 2). This objective was fully accomplished under the current grant.

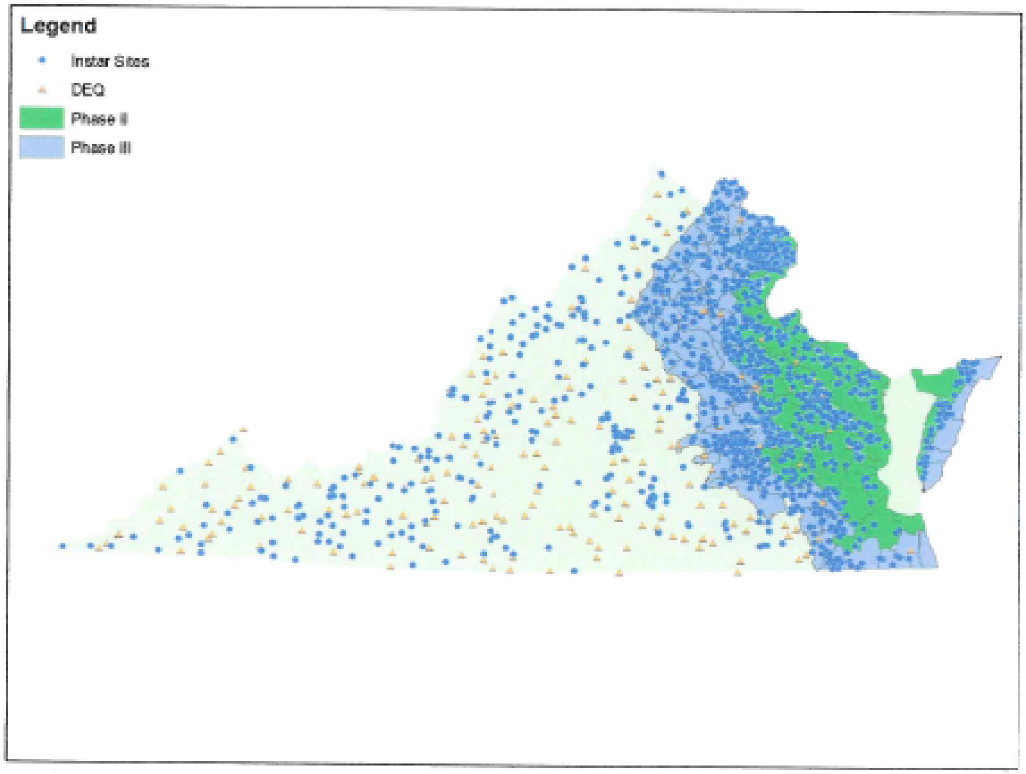


Figure 2. Current distribution of INSTAR stream locations and of the DEQ's Probabilistic Monitoring (ProbMon) stations, which are integrated into the INSTAR database.

4.) Outreach Efforts

During the project period, members of the INSTAR team, including G. Garman, L. Smock, and W. Shuart, participated in at least 20 formal and informal meetings regarding development of INSTAR as a decision support tool. At most of these meetings, VCU gave a presentation and conducted an online demonstration of the INSTAR application. Copies of selected Powerpoint presentations are available upon request. Groups represented in these events included a wide range of state, federal, and local (municipal, county, PDC) government entities, as well as academic institutions and NGOs. This objective was fully accomplished under this grant.